B.C. Hydro
Alberta Interconnected System
Generation Coordination Study

March 22, 1989

B.C. Hydro
Resource Planning

TransAlta Utilities
Power Planning

Summary

The B.C. Hydro system and the Alberta Interconnected System (A.I.S.) differ significantly in their generation mix. B.C. Hydro's generation system is predominantly hydro, while the A.I.S. generation system is predominantly coal-fired. The purpose of the B.C. Hydro-A.I.S. Generation Coordination Study was to identify the benefits from increased coordinated operations and coordinated construction of new facilities.

Current Coordination

While current coordination efforts already offer significant benefits as a result of reduced planned resource additions, the B.C. Hydro - A.I.S. Generation Coordination Study has attempted to estimate the additional potential benefits from increased coordination between B.C. Hydro and the A.I.S. over the time period 1990-2010. The base case assumes that the current level of coordination between the two systems continues into the future.

Coordinated Operation

Full coordinated operation alone could reduce costs, primarily by the increased utilization of Alberta's coal-fired generation during light load periods. The result would be reduced overall operating costs in Alberta or increased economy exports to the U.S.

Coordinated Construction

In addition, coordinated construction of new generation facilities could delay the construction of new generation projects otherwise planned for the combined system. This is possible due to the inherent surplus hydro peak capacity on the B.C. Hydro system and surplus energy on the A.I.S.

Four Options for Coordination

In this study, four different options have been reviewed and compared to the base case. Following is a brief description of the four options and their impacts:

Option One
- Coordinated operation
- Results: Lower operating costs

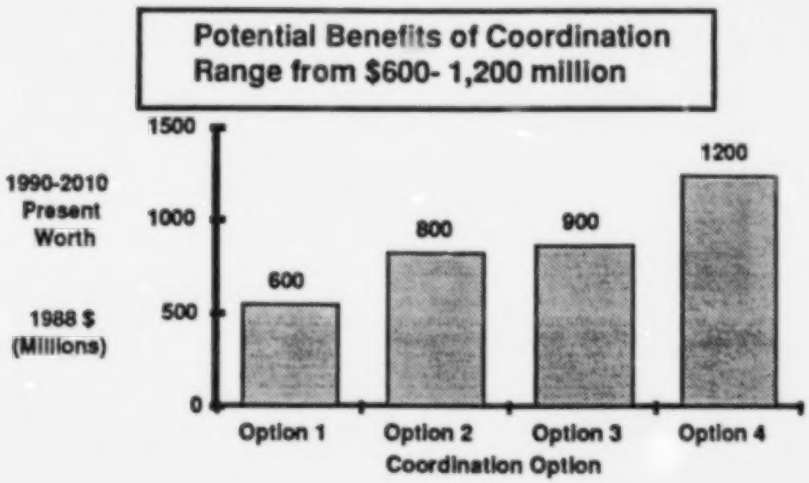
Option Two
- Coordinated operation and construction
- Retain the planned order of new projects on each system with maximum deferral according to the combined system needs.
- Results: Additional savings through deferral of projects on both systems.

Option Three
- Coordinated operation and construction
- Planned A.I.S. combustion turbines replaced with B.C. hydro generation.
- Results: Savings further increased with the addition of low-cost capacity on the B.C. Hydro system.

Option Four
- Coordinated operation and construction
- Coal-fired generation built on A.I.S. to meet energy needs on both systems and hydro peaking capacity built on the B.C. Hydro system to meet peaking needs on both systems.
- Results: Maximum savings with increased reliance on Alberta coal-fired plants

Cost Reduced By As Much As $1.2 billion

The combined systems could reduce generation costs by 600 million to 1.2 billion dollars, depending on the nature of construction coordination.



Transmission Limitations Not Assessed

As a first step in a complex process, the focus of this specific study was limited to identifying the generation related benefits exclusively, without consideration of the transmission limitations between and within the two systems. The actual benefits of coordination will be lower than the values reported here, since the two systems will need to strengthen the combined transmission network to different degrees depending on the selected option.

Short Term Non-Firm Export Sales Not Significantly Affected

Short-term, non-firm sales to the United States would continue to play an important role, regardless of the coordination option selected. The combined B.C. Hydro/A.I.S. System was able to maintain similar levels of non-firm sales based on the assumptions of the market and current transmission limits to the United States. Of all the cases, Option 1, the operating coordination case, showed the most potential for increasing exports from the levels B.C. Hydro expects while operating independently.

Firm Power Exports Not Assessed

The study did not attempt to assess the potential to utilize the combined system capability to export firm power. However, there may be potential, particularly in Option 1, to package B.C. Hydro's surplus capacity and surplus energy on the A.I.S into a firm power sale. This potential would be reduced in the other options as the surplus capacity and energy are committed to the combined needs of B.C. Hydro and the A.I.S.

Cost Reductions Not Allocated

Throughout this study, no attempt has been made to allocate the benefits between the two systems. Business arrangements, including cost and benefit allocation mechanisms, will be required before this can be done.

Further Study

Further study will be carried out in the following areas:

1. Transmission systems in both provinces will be studied, to identify costs, capability increases and benefits of incremental additions of transmission capacity.
2. An analysis will be carried out to identify the potential of the combined BCH and A.I.S. system to supply a large firm load.
3. A sensitivity analysis will be performed to evaluate the impact of future uncertainties such as load growth, United States short-term non-firm market, fuel costs and financial parameters on the potential benefits of generation coordination.
4. Studies will be undertaken to evaluate incremental increases in operating co-ordination.

1. Background

Electric utility system cooperation between B. C. Hydro and TransAlta Utilities has been in effect for more than 50 years.

Since that time, many studies have been undertaken which were intended to take advantage of the complementary nature of the two provinces' respective electric generation sources. Two such examples are:

- a 1976 study highlighting the significant economic benefits from improved transmission interconnection, and the subsequent coordinated operation and planning of the two systems, which lead to the current 500 kV interconnection, and
- a 1984 study highlighting the potential benefits of increased coordination between the two systems.

In early 1988, B.C. Hydro and TransAlta Utilities agreed that a generation co-ordination study should be undertaken. This report summarizes the results of the study.

Study Objective

The objective of this study was:

"to estimate the potential economic benefits from coordination of B.C. Hydro and A.I.S. systems ranging from operating cooperation to full resource planning integration over the time period 1990-2010."

The specific terms of reference of the study were to:

- Update the joint study by B.C. Hydro and TransAlta Utilities dated May 1984 which identified possible benefits of coordinated resource planning, and
- Identify follow-on studies and a study schedule that would quantify the benefits and costs including transmission limitations and additional facilities.

Study Team

The study was jointly prepared by the staff of B.C. Hydro's Resource Planning Department and TransAlta Utilities' Power Planning Department.

2. Methodology

This study reviews a range of coordination options from operational coordination to coordinated operation and construction. These options were selected to estimate the benefits of generation coordination excluding transmission limitations. This was done for simplicity as transmission constraints add significantly to the complexity of the study. It was recognized that transmission

additions could reduce the estimated benefits of coordination and potentially change the economic ranking of the options, however, the main goal of this study was to explore the broad outlines of potential mutual benefits from coordination and to recommend further detailed studies.

Each utility provided its estimates of production costs for its existing system, as well as capital and production costs and schedules for new resource options.

Total cost for each level of generation coordination was calculated for each of the 21 years (1990 to 2010 inclusive) and the present value calculated in 1988 dollars.

Resource Scheduling

Resource schedules were developed for each level using B.C. Hydro's resource planning models. These models determine the need for new resources to meet the combined systems' forecast energy load by the most cost effective means.

Resource development sequences were first developed to minimize long-term costs of system expansion. Selective advancements were then made to ensure satisfactory energy reliability requirements.

The sequences were then tested to meet a capacity criterion which set a minimum capacity level at a Loss of Load Expectance of 0.2 peak days per year.

Production Simulation

B.C. Hydro and TransAlta have each developed significant expertise at simulating the operation of their individual systems. B.C. Hydro is expert at modelling hydro, or energy-constrained systems, while TransAlta is expert at modelling thermal, or capacity-constrained systems. For this study, the two utilities combined their processes to develop an overall hydro-thermal simulation.

For each level, B.C. Hydro developed an optimum multi-year reservoir operating plan and, from that, monthly hydro outputs for their system. TransAlta then combined these monthly hydro energy outputs with the combined system's thermal capabilities in to calculate monthly energy production for the thermal resources.

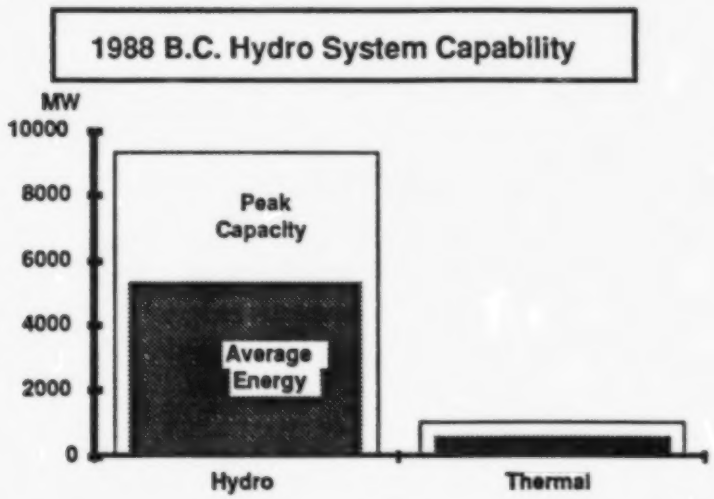
Once energy needs of the combined system were met, surplus energy and capacity were then evaluated for their export potential to the U.S. as short-term spot market energy.

3. Current and Committed System

B.C. Hydro

B.C. Hydro's system consists predominantly of hydroelectric plants with only limited thermal generation. New plants are generally added to provide more energy capability.[1] However, scheduling new hydro plants to provide the required energy (MWa) tends to result in surplus generating capacity (MW).

B.C. Hydro currently has 9477 MW of dependable hydro capacity which can produce 5350 MWa. This can range from 5040 to 5970 MWa, depending on streamflow conditions. B.C. Hydro also has gas-fired generation with a total capacity of 1046 MW, which can produce 425 MWa.



B.C. Hydro's resource plans identify 2400 MW of scheduled new energy resources as well as 3400 MW of planned new generation facilities which are not yet committed.

The following future supply sources are assumed to be committed for this study:

- *Demand-Side Management*

  Customer conservation to reduce energy use.

1 Hydro Systems are generally energy limited which means that the capability to produce megawatt-hours (called average megawatts (MWa)) is limited by availability of water. On the other hand, thermal systems are generally capacity limited, which means that the plant capacity, rather than energy source (fuel) is the limiting factor.

- *Columbia River Coordination with Bonneville Power (BPA)*

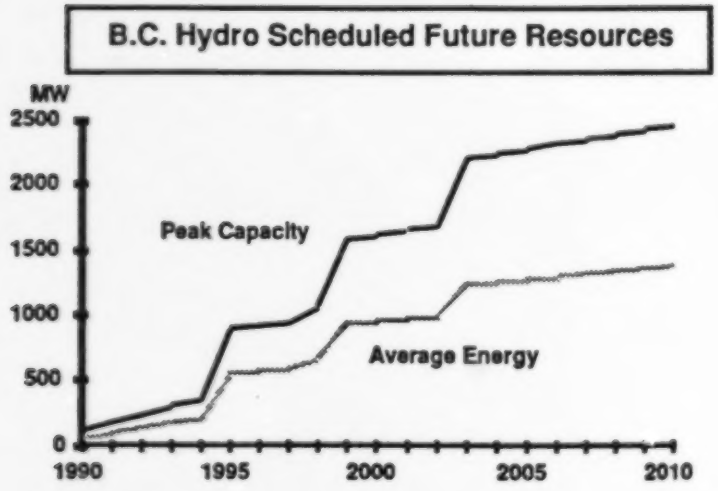
  Increased coordination of B.C. Hydro and BPA storage reservoirs on the Columbia would increase B.C. Hydro's firm energy capability.

- *Coordination/purchase agreement with Alcan*

  B.C. Hydro is nearing completion of an agreement with Alcan to purchase excess capacity and energy from Alcan's Kemano generating plant.

- *Return of Columbia River Downstream Benefits*

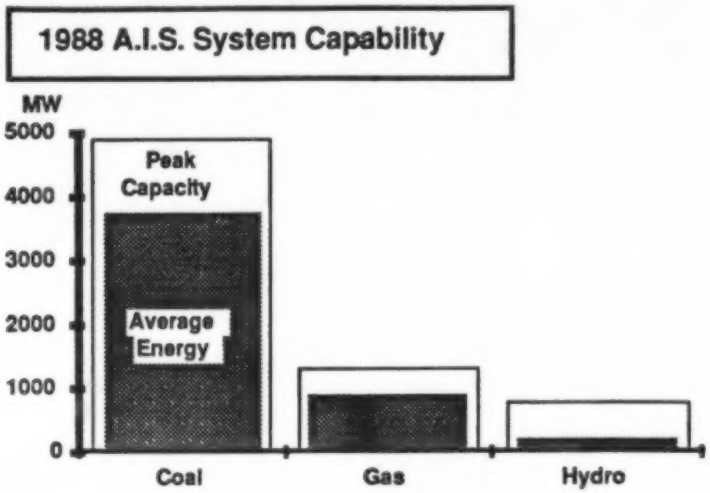
  The Canadian entitlement to downstream power and energy benefits from the operation of the original Canadian hydro projects on the Columbia was sold to the U.S. for 30 years. Those benefits revert to B.C. starting in 1998/99.



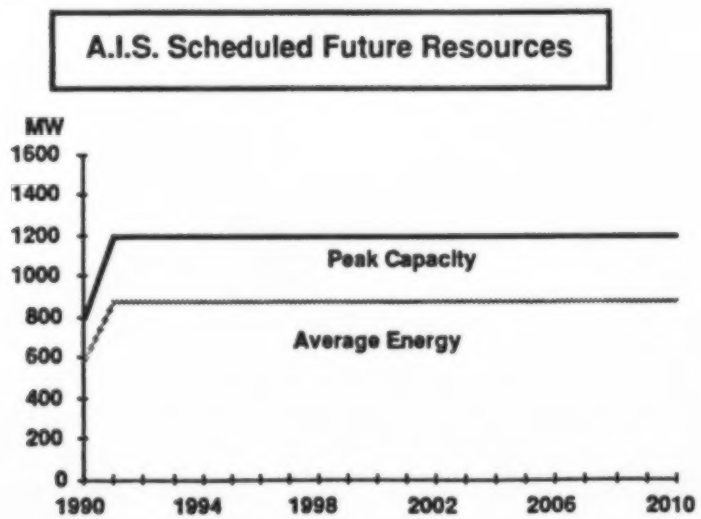
A.I.S.

The A.I.S. consists predominantly of coal-fired plants, with a limited amount of hydro generation. The A.I.S. will become capacity limited and new generating units will be required to meet an established capacity criterion. Being a thermal system, no storage capability is available to allow the shifting of energy production from one time of day to another. As a result, surplus energy is available during low load periods when thermal resources are not being fully utilized.

The A.I.S. has 4897 MW of coal-fired generating capacity, capable of producing 3749 MWa per year and 1332 MW of gas-fired generation, capable of producing 910 MWa. It also has 795 MW of hydro capability, capable of producing 188 MWa.



The A.I.S. plans identify 1195 MW of committed new capacity as well as the need for an additional 8700 MW of new capacity by the year 2010.



A.I.S. commitments through the study period are to complete the three 400-MW coal-fired generating units, Genesee 1 and 2 and Sheerness 2, as well as to retire a number of thermal generating units.

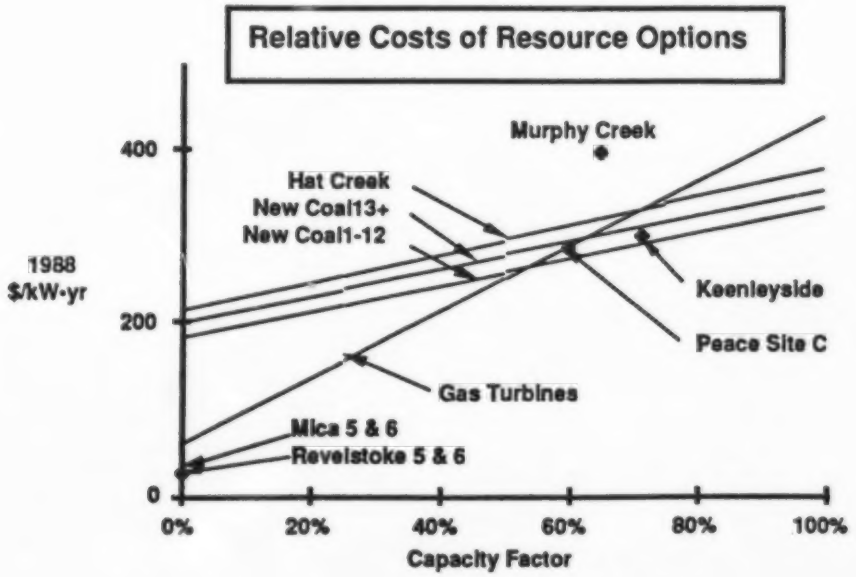
4. Resource Options

Current resource options for each system include the following.

	Peak Capacity MW	Average Capability MW
B.C. Hydro		
Peace Site C	900	536
Keenleyside	240	120
Murphy Creek	275	175
Hat Creek(coal)	2,000	1,500
Mica 5, 6	800	0
Revelstoke 5, 6	900	0
A.I.S.		
New Coal(first 12 units)*	375	277
New Coal (after first 12)*	375	277
Gas Turbines*	100	74

* per unit

Each option's characteristics, i.e., size, cash flows, internal transmission costs, and capability are summarized into an overall value as energy producing or peaking resource.



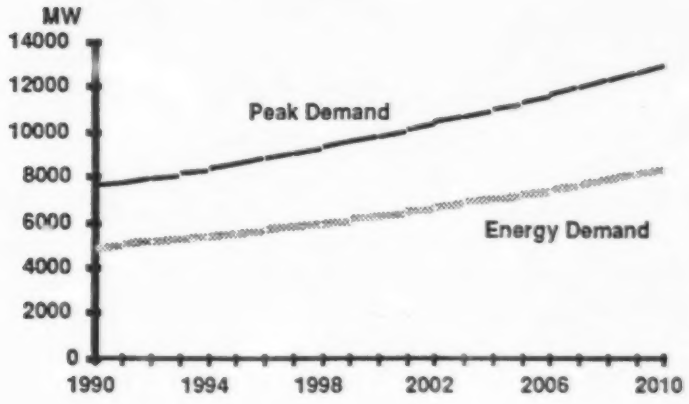
5. Forecasts

Three key variables in this study were forecast customer demand, natural gas prices and export market. The assumptions, and their sources are documented here.

Customer Demand

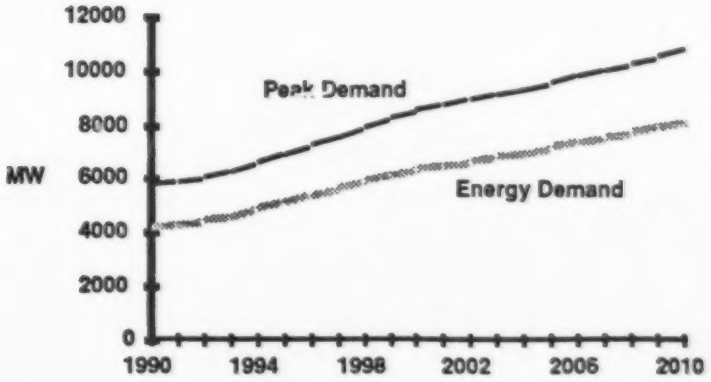
The B.C. Hydro electric demand forecast is based on its July 1987 Electric Load Forecast.

B.C. Hydro Electric Demand Forecast



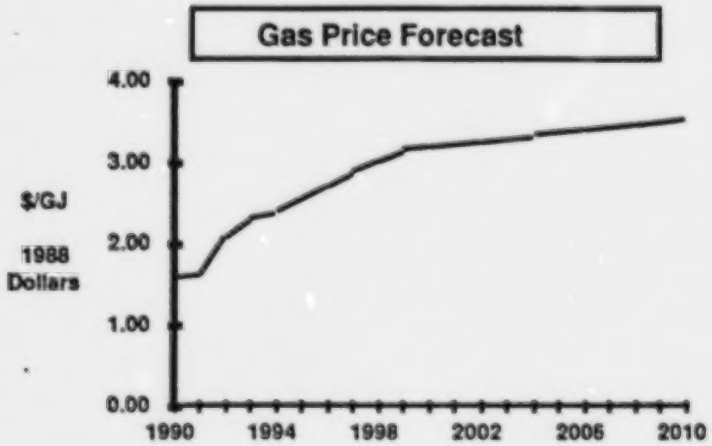
The A.I.S. electric demand forecast is based on the TransAlta 1987 Mid Forecast.

A.I.S. Electric Demand Forecast



Natural Gas Prices

The natural gas price forecast is based on the TransAlta 1987 Mid Forecast.



Non-Firm Export Market

The size and value of the U.S. market for short-term non-firm energy has been forecast by B.C. Hydro. The model, which is a simplified representation of the U.S. Pacific Southwest and Northwest markets, is used to identify the amount of revenue from non-firm export sales. The market size is assumed to be constant from year to year throughout the 20-year period, varying only with water conditions.

Prices are assumed to rise at the rate of inflation. The potential market volumes have been limited to amounts of energy that can be transmitted over currently operating or planned transmission.

U.S. Market Assumptions
(1988 price levels)

	Market Size (MWa)	Market Value ($/MW.h)
Pacific Southwest	422	21.0
Pacific Northwest 1	268	18.4
Pacific Northwest 2	211	13.8

6. Base Case

A certain amount of generation coordination is already taking place between the two provinces. B.C. Hydro depends on the A.I.S. for up to 4000 GWh/year of non-firm energy. The A.I.S. depends on B.C. Hydro for 300 MW of capacity reserve.

This study assumes that this level of coordination is part of the current operating practices. Benefits identified in this report only result from increased coordination.

Non-firm exports to the U.S. are very important to B.C. Hydro. The utility currently receives a significant portion of its revenue from short-term economy energy exports, and this is expected to continue.

B.C. Hydro's net revenue from short-term economy energy exports to the U.S. is estimated to be $300-400 million present worth, throughout the study period, without further generation coordination. For each coordination level studied, the potential to export short-term economy energy is compared to this currently expected export revenue.

7. Results

Four options of generation coordination were studied and compared to current generation coordination practices.

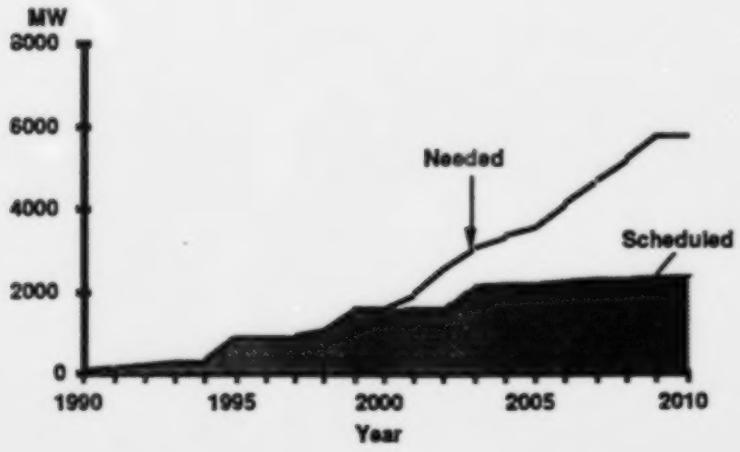
Option One

The two systems continue to construct new generation facilities to meet their own needs, as if they were independent. The two systems then operate as if they were one system.

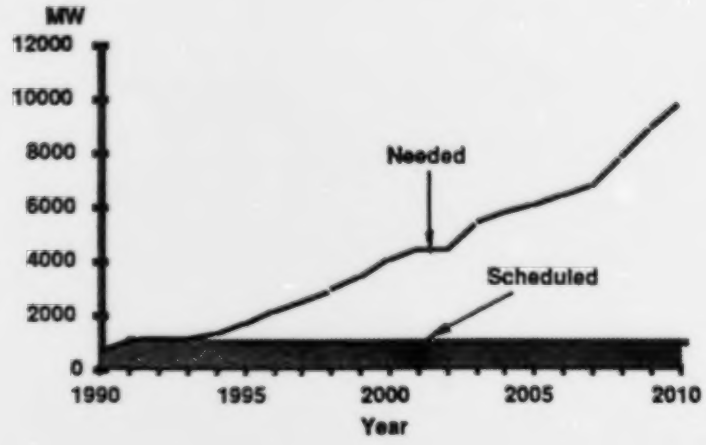
Such full operational coordination would involve no change to planned capacity additions. Each system would continue to build new generation facilities to meet its customers' demand. The benefits would result from taking advantage of full economic dispatch, reservoir scheduling and maintenance planning.

This option could commence without adjusting the transmission system. However, transmission improvements may be required to attain the full benefit of operating coordination. Since no generating capacity is deferred in either province, neither system would be increasing its dependence on the other for firm long-term support.

Option One B.C. Hydro Resource Additions

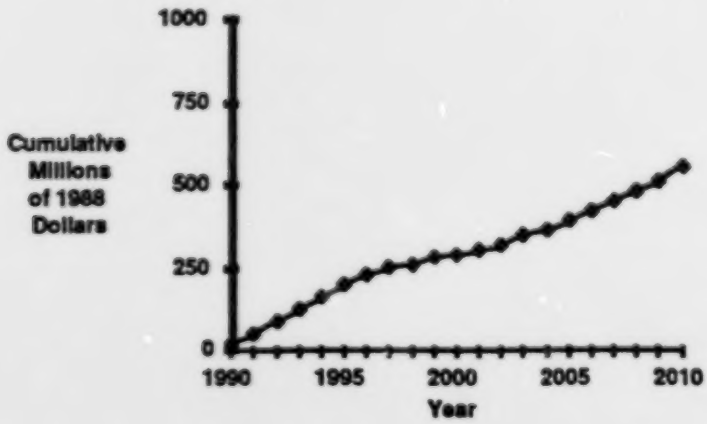


Option One A.I.S. Resource Additions



With this option, the two areas could expect to reduce their overall costs for the study period by up to $600 million. This benefit would result from a reduction in operating costs and increased non-firm export sales.

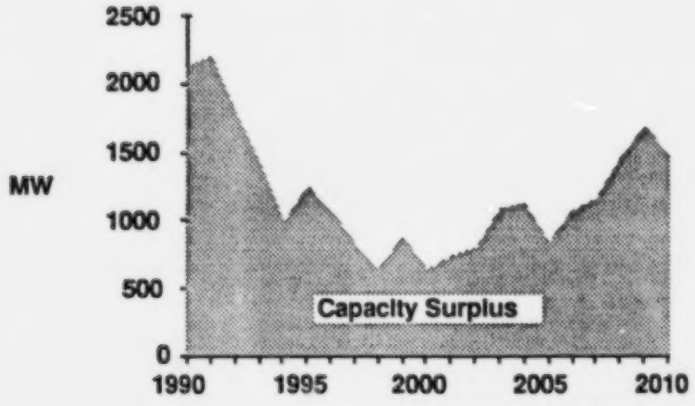
Option One Benefits are $600 Million



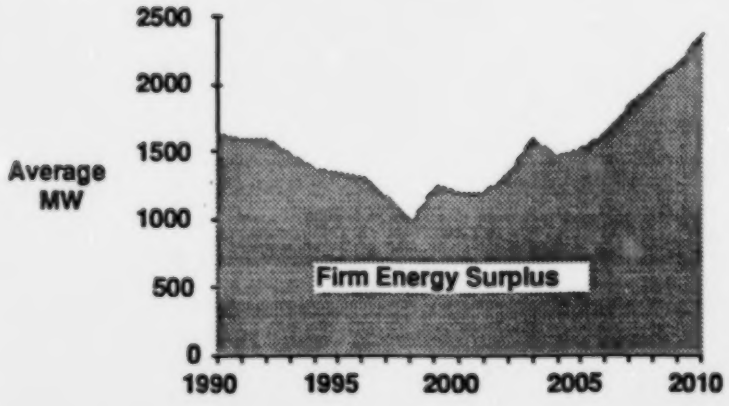
In Option 1, each area retains the ability to meet its own customer demand. By retaining this ability, the combined system will have inherent surplus capability.

Once the combined system internal demand and non-firm exports are met, there remains more than 600 MW of capacity surplus and over 1000 MWa of firm energy surplus. This surplus is utilized in Options 2,3 and 4 to defer plants in the two provinces.

Option One Capacity Surplus



Option One Firm Energy Surplus



Option Two

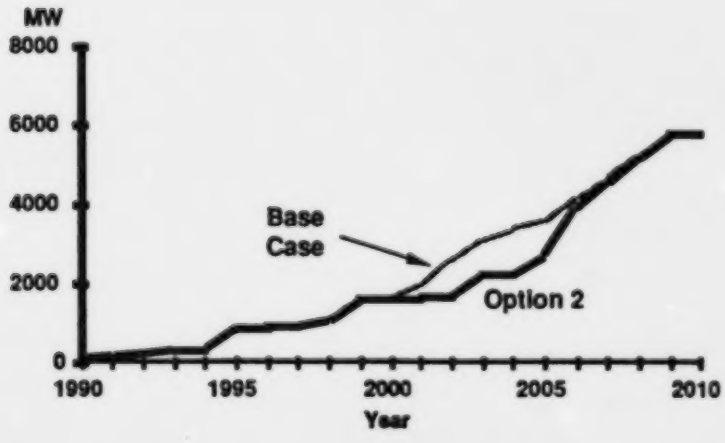
The two systems defer the timing of new generation facilities until the resources are required for the combined system. The order of development which would occur if the utilities developed the projects independently is still maintained. This option results in about the same proportion of projects being constructed in B.C. as in Alberta.

By combining the B.C. Hydro-A.I.S. system, the total generation requirements would be reduced, as the combined system would require less reserve than the sum of each individual system's reserve requirements.

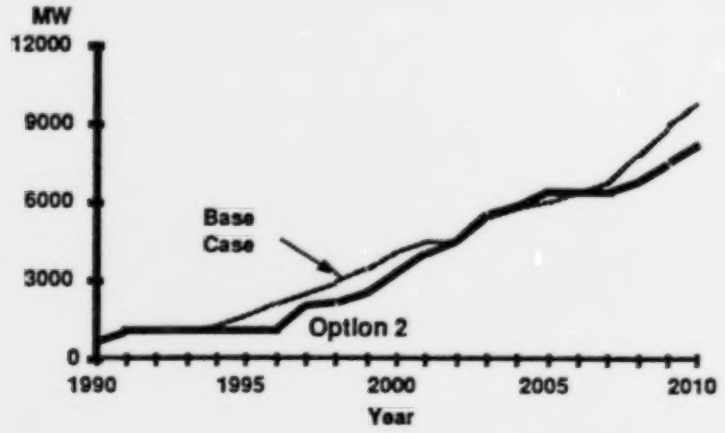
This option would result in the deferral of new facilities in both provinces because of the lower overall reserve requirements. Both reduced operating and capital costs would occur.

As a result of the deferrals, each system would become more dependent on the other to ensure that customer demand is met. Sufficient transmission capacity would have to be available to allow the flow of firm power commitments from one system to the other.

Option Two B.C. Hydro Resource Additions

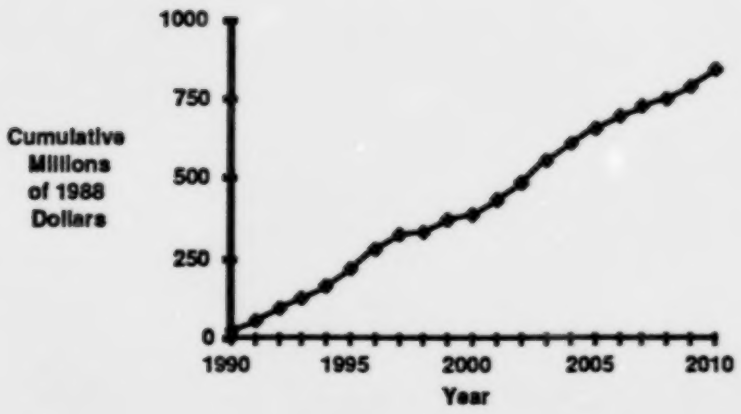


Option Two A.I.S. Resource Additions



This coordination option would reduce net costs by approximately $800 million over the study period. The benefit would result primarily from the deferral of capital expenditures and reduced operating costs.

Option Two Benefits are $800 Million



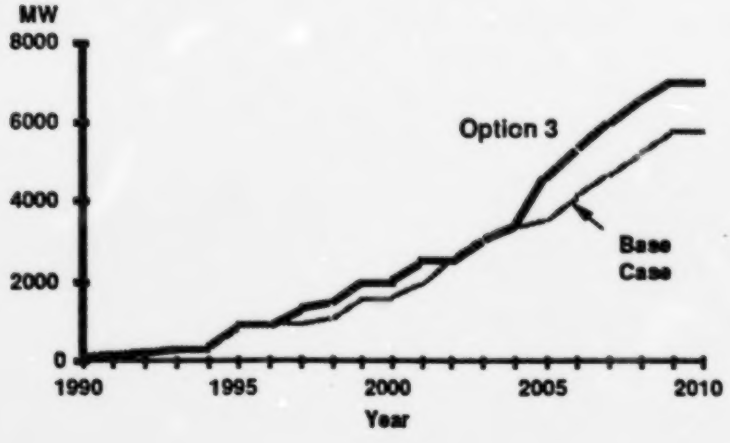
Option Three

The two systems defer the timing of new generation facilities until the resources are required for the combined systems. All gas turbines planned for the A.I.S. would be replaced by hydro projects in B.C.

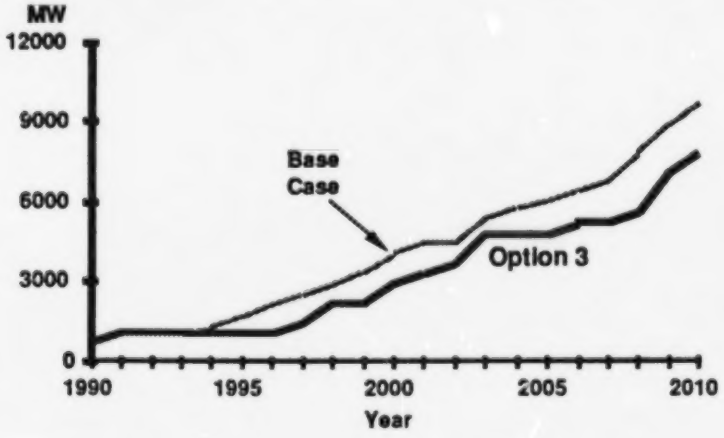
This option results in more projects being constructed in B.C. than Alberta, with a significant alteration in the balance of resources between the two provinces. B.C. Hydro would construct additional peaking capacity, and advance some energy-producing plants to eliminate the need for the planned gas turbines in Alberta.

Large on-peak transfers of energy from B.C. Hydro to the A.I.S. would occur on a regular basis under this option. Nearly 2000 MW less gas-fired generation would be constructed in Alberta by the end of the study period. Transmission would have to be significantly strengthened to ensure that the A.I.S. could maintain a reliable supply of electricity to its customers.

Option Three B.C. Hydro Resource Additions

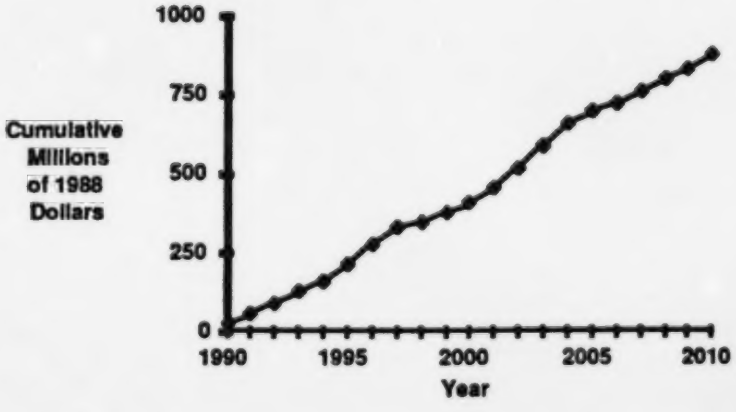


Option Three A.I.S. Resource Additions



Coordination option 3 would result in approximately $900 million of benefits, due to decreased capital expenditures and operating costs.

Option Three Benefits are $ 900 Million



Option Four

The two systems develop new generation facilities based on the economics and need of the combined system. Coal-fired units would be constructed in Alberta when projects are required for energy purposes, and peaking turbines would be installed at existing hydro plants in B.C. when projects are required for capacity purposes. This option results in a higher proportion of projects being constructed in Alberta than in B.C.

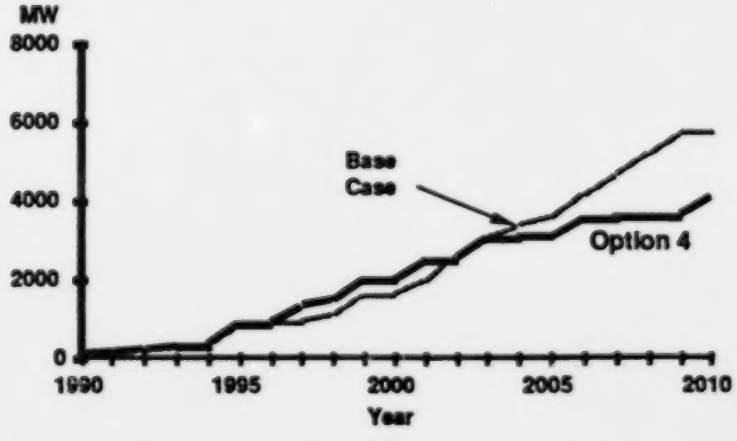
Coal-fired generation in Alberta was identified as the lowest-cost source of base load generation. Any required peaking capacity could be met by adding two more units at both the Mica and Revelstoke hydro plants.

Initially, with this option, new base-load generation facilities would be deferred, as the combined system's surplus was depleted. Construction would occur at a more rapid pace near the end of the study period to meet both systems' energy needs. B.C. Hydro would construct some peaking capacity in advance of its own needs, and defer all new hydro energy projects past the end of the study period.

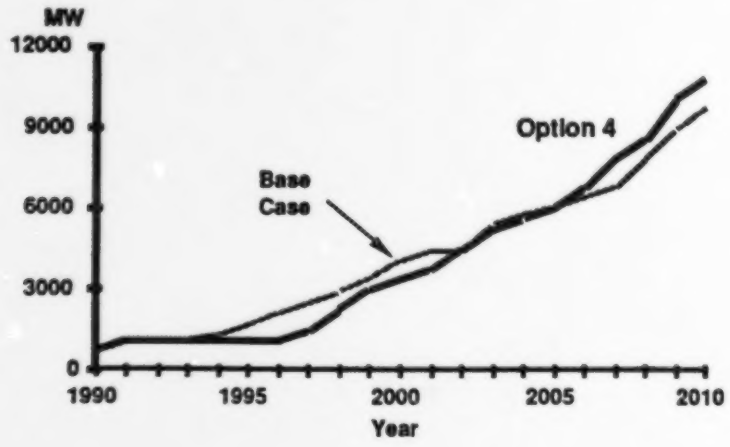
By the end of the study period, the A.I.S. would be supplying large amounts of energy to B.C. Hydro on a continuous basis. B.C. Hydro would be constructing nearly 1700 MW less generation by the year 2010 than currently planned.

Transmission would have to be significantly strengthened to ensure that B.C. Hydro could reliably maintain the supply of electricity to its customers.

Option Four B.C. Hydro Resource Additions

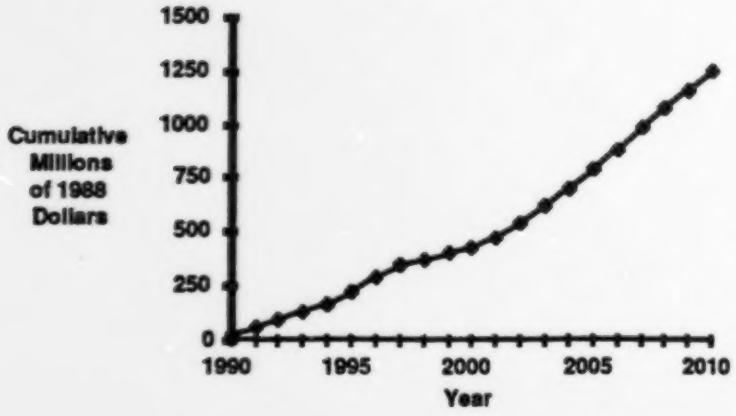


Option Four A.I.S. Resource Additions



Benefits of implementing this option is the greatest of any option studied. Total benefits would be $1.2 billion, as a result of deferred capital expenditures and reduced operating costs.

Option Four Benefits are $1.2 Billion



8. Follow-on Studies
• Action Plan
• Further Studies

Results of this study indicate that there is potential for significant benefits to Alberta and British Columbia through increased coordination.

However, certain studies are required before further coordination can take place. Additional study will be undertaken as described below to be completed by June 30th, 1989.

1. Transmission Analysis

   This study assumed that there would be no transmission limitations.

   A study will be undertaken to identify the changes in costs and benefits which would occur as the transmission network is incrementally strengthened.

2. Firm Capability

   An analysis will be undertaken of the abililty of the combined resources of BCH and the A.I.S. to supply a large firm load.

3 Sensitivity Analysis

   Sensitivity studies will be performed to evaluate the impact of certain variables on potential benefits of generation coordination. Sensitivity studies will include the key variables identified in this study, i.e., load growth, gas prices and short-term export market, as well as variations in financial and economic parameters.

4. Operational Co-ordination

   Studies will also be undertaken to calculate the operating benefits resulting from incremental increases in operating co-ordination from current practices to one system operation.